1998–99 CATS ASSESSMENT
Open-Response Item Scoring Worksheet

Grade 11 Science

The **academic expectations** addressed by "Motion and Energy of Molecules" are

2.2 Students identify, analyze, and use patterns such as cycles and trends to understand past and present events and predict future events.

2.3 Students identify and analyze systems and the ways their components work together or affect each other.

The **core content** assessed by this item includes

Content

- Objects change their motion only when a net force is applied. Laws of motion are used to predict and/or calculate the effects of forces on motion of objects.
- The physical properties of compounds reflect the nature of the interactions among their molecules.

Motion and Energy of Molecules

All molecules contain energy. Give a complete description of the motion and energy of the molecules of a substance as that substance changes from a solid, to a liquid, to a gas.

SCORING GUIDE
Grade 11 Science

Score	Description
4	The response is complete and shows a solid understanding of the relationship among molecular motion, energy, and the states of matter. There is a clear, accurate description of the movement and energy of molecules as a substance changes from a solid, to a liquid, to a gas.
3	The response shows an understanding of the relationship between molecular motion, energy, and the states of matter. There is a clear description of the movement and energy of molecules in a solid, a liquid, and a gas, but the response lacks detail or contains minor errors or misconceptions.
2	The response shows a limited understanding of the relationship between molecular motion, energy, and the states of matter. There is a description of the movement and/or energy of molecules in a solid, a liquid, and a gas, however, the response may contain errors, misconceptions, or omissions.
1	The response shows a minimal understanding of the relationship between molecular motion, energy, and the states of matter. There is a description of the movement and/or energy of molecules in a solid, or a liquid, or a gas, however, the response is mostly incorrect or contains major errors and omissions.
0	Response is totally incorrect or irrelevant.
Blank	No response.

Science Behind the Question:

Solids can change to liquids and liquids to gases under isothermal or conditions of increasing temperature. Students are much more familiar with the latter case, so their description will generally assume that molecular kinetic energy will be increasing.

All particles of matter are in a constant state of motion. The more kinetic energy they have, the faster they move. Temperature is a measure of the total kinetic energy. As the kinetic energy of a substance increases, an increase in molecular movement results until the substance changes from one state to another (when the temperature reaches the melting or boiling point). In a solid, particles are arranged in repeating geometric patterns held together by forces that keep them in position. A solid holds its shape because, although the particles vibrate, they do not move over or around each other. As energy is added to a solid, its molecular motion and temperature will increase until it reaches the melting point. At that point, the energy is used to overcome the forces holding the particles in place, and the substance changes to a liquid as the temperature stays constant. In a liquid, the particles are moving faster, but they are still close together. They have enough kinetic energy (in relation to the energy of possible attractive forces) to move past one another, thus a liquid can flow. More energy will again cause an increase in temperature until there is enough energy that the substance changes to a gas at the boiling point. At this temperature, particles have enough energy to separate completely from one another. The potential energy of the molecules changes as a substance changes state. When molecules in a substance are close together, the molecules have more potential energy.

ANNOTATED STUDENT RESPONSE
Grade 11 Science

Sample 4-Point Response of Student Work

Student Response

All molecules contain energy. The motion and energy of the molecules of a substance change as the substance changes from a solid, to a liquid, to a gas. When a molecule is changing from a solid to a liquid, the molecules become farther apart and move around more quickly and don't have much order. This is different from a solid in which the molecules barely move and are close and orderly. Changing from a solid to a liquid is usually done by melting or heating the solid. Raising the temperature gives the molecules more energy. An example is ice. When ice is being melted it doesn't keep the same form.

Heating a substance can also make the substance change from a liquid to a gas. The molecules are very far apart and are in total chaos, moving and colliding with each other at relatively high speeds. Taking the ice example further, ice can change to water and then gas as the temperature, and therefore energy, increases.

← Student clearly and accurately describes the change from a solid to a liquid state in terms of the increased spacing between molecules and the increased motion (including speed) and disorder of the molecules. The description conveys that the change of state is accomplished by adding energy to the system.

← Student clearly and accurately describes the change from a liquid to a gas state in terms of increased spacing between molecules and the increased motion and disorder of the molecules, again referencing the roles of heat and energy.

Overall, the response demonstrates a solid understanding of the relationship among molecular motion, energy, and states of matter.

ANNOTATED STUDENT RESPONSE
Grade 11 Science

Sample 4-Point Response of Student Work

Student Response

All molecules contain energy. While the molecules are in the solid state, the energy level is low and they are not moving around much. Then, their energy increases and they start moving a little faster. This is when they go from a solid to a liquid. Then, they get a lot of energy and start moving really fast. This is when they go from a liquid to a gas. As the molecules get faster throughout the process, they spread further apart from one another.

Student clearly and accurately describes the change from a solid, to a liquid, to a gas state in terms of increased energy, increased molecular speed, and increased spacing between molecules.

Overall, the response demonstrates a solid understanding of the relationship among molecular motion, energy, and states of matter.

ANNOTATED STUDENT RESPONSE
Grade 11 Science

Sample 3-Point Response of Student Work

Student Response

The molecules contained in a solid are slow, and sluggish. They hardly move at all, and when they do, they move very slowly. The energy levels is at an all-time low, due to the slow-moving molecules.

As the solid changes to a liquid, the molecules pick up their pace. They begin to move rather quickly, their speed increasing. They are fast and they move quickly and efficiently. The energy level gets quite a boost. The molecules intense level of activity produces much more energy than in a solid and the energy level is raised quite a bit.

Finally, as the liquid converts to a gas, the molecules take on lighting speed. They dart cleanly around at unimaginable speeds, producing endless amounts of energy.

← Student describes molecules in the solid state in terms of energy and molecular speed.

← Student describes the change from a solid to a liquid state in terms of increased energy and molecular speed. There is no mention of the changes in the spacing between molecules.

← Student describes the change from a liquid to a gas state in terms of energy and molecular speed. Again, no mention is made of the change in the spacing between molecules.

Overall, the response demonstrates understanding of the relationship between molecular motion, energy, and the states of matter, though the response lacks some detail (e.g., doesn't address the issue of spacing between molecules in the different states of matter).

ANNOTATED STUDENT RESPONSE
Grade 11 Science

Sample 2-Point Response of Student Work

Student Response

I am going to give you a description of the motion and energy of the molecules of a substance as the substance changes from a solid, to a liquid, to a gas. When a substance is a solid, the molecules are slow and are not moving very rapidly.

When it becomes a liquid the molecules become faster and the energy is up. When it becomes a gas the molecules speed up very fast and the motion is back and forth.

The student describes molecules in the solid state only in terms of molecular speed. Energy and the spacing between molecules are not addressed.

The student describes the change from a solid, to a liquid, to a gas state in terms of increased energy and molecular speed, though the reference to energy is weak. It is a misconception that "back and forth" motion occurs only in the gas state.

Overall, the response demonstrates a limited understanding of the relationship between molecular motion, energy, and the states of matter. The response does not adequately address energy or the issue of spacing between molecules in the different states of matter.

Sample 1-Point Response of Student Work

Student Response

All molecules do contain energy. However, molecules are like people, no two molecules are alike. You can not talk about them in general.

In my chemistry class, we talked about many different types. Some of which were more confussing then the next. Today, however, I am going to talk about something we are all familiar with: H2O, also known as water or ice.

In solid form H2O is referred to as ice, the process of it changing from solid to liquid form is called melting. During this process, the molecules speed up and are moving very rapidly. The next stage, is called evapration ("evaporation"). This is the point where it changes from a liquid into a gas. At this point, the molecules have slowed down and the sun does the rest of the work.

The student correctly describes molecules as containing energy, but molecules (of the same substance) are much more alike than people.

The student describes the change from a solid to a liquid state only in terms of increased speed of molecules.

The student incorrectly describes the change from a liquid to a gas. The molecules do not slow down; they speed up.

Overall, the response demonstrates a minimal understanding of the relationship between molecular motion, energy, and the states of matter.

INSTRUCTIONAL STRATEGIES
Grade 11 Science

The open response item **"Motion and Energy of Molecules"** was designed to assess students' ability to describe changes of state (from a solid, to a liquid, to a gas) in terms of molecular motion (speed and velocity) and energy. In order to answer successfully, students needed to recall all of the experience they have had with examining changes of state over several grade levels, and combine this with knowledge learned in upper grades about how molecules typically behave in the different states of matter. The instructional strategies below present ideas for helping students explore and master relevant concepts and descriptive and communication skills.

Discuss the following concepts and skills with students:

- The molecular nature of matter
- Physical properties of substances are mostly dependent on forces (intermolecular) between one molecule and another. When intermolecular forces are stronger, the substance is more likely to be a solid. When intermolecular forces are weaker, a gas results.
- The kinetic-molecular model of matter (molecules are constantly in motion)
- The state in which a substance is found depends on a balance between the kinetic energy of the molecules and the intermolecular forces. In general (though there are special exceptions), as heat energy transfers to a pure solid substance, the kinetic energy is increased and the intermolecular forces are not strong enough to hold the molecules as tightly. Therefore, a change of state occurs.

Have students work individually, in pairs, in small groups, and/or as a class to complete any or all of the following activities:

- Create an animated cartoon video or computer model showing how a substance changes from a solid to a liquid or a liquid to a gas.
- Create models, including revisions of models experienced in earlier grades (e.g., hand holding in the classroom), that demonstrate molecular behavior in a solid, liquid, and gas. Prepare an oral report on how well the model matches what occurs during state changes.
- Create heating/cooling curves for water or another substance from solid to liquid or liquid to solid by monitoring temperature changes as a function of time. Investigate how this varies with (1) heating rate (2) amount of substance, and (3) type of substance (e.g., covalent versus ionic, polar covalent versus nonpolar covalent). Use molecular descriptions to describe what happens.